

4533K10-001

INSTRUCTIONS

TYPE 524
CURRENT-MODULATION CONTROLLER

PRELIMINARY COPY

(Fig. 1. Typical current-modulation controller)

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INTRODUCTION

GENERAL

These instructions cover the installation, operation, and maintenance of the General Electric Type 524 Current-Modulation Controller. This controller is installed with a General Electric Type HF, HR, HT, 520, or 521 strip-chart recorder, all of which have a 5.0K 100% control slidewire or a provision for adding one. The function of the controller is to provide a 10 to 50 ma control signal for a final-control element such as a magnetic amplifier and saturable reactor, an electro-pneumatic or electro-hydraulic valve operator, or a silicon controller-rectifier. The Type 524 Current-Modulation Controller provides both manual and automatic process control.

SPECIFICATIONS

Input Signal:	Error Signal from Indicators or Recorders such as General Electric Types HF, HR, HT, 520, and 521, which have 5.0K Slidewires
Slidewire Supply Voltage:	8.0 ± 0.5 VDC
Output Signal:	10 to 50 MA into 0 to $600 \pm 10\%$ Ohms
Control Methods:	Manual and Automatic
Automatic Control Modes:	3 (Proportional, Reset, and Rate)
Proportional Band:	2 to 500% (Gain of 50 to 0.2)
Reset Range:	0.04 to 10 Repeats per Minute (25 to 0.1 Minutes)
Rate Range:	0.1 to 25 Minutes
Approximate Rate Gain:	10
Power Requirement:	107 to 127 VAC, 50/60 $\pm$ 1 CPS, 20 WATTS
Ambient Temperature Range: (Continuous Operation)	+40°F to +120°F
Ambient Temperature Range: (Non-Continuous Operation)	+40°F to +140°F
Ambient Operational Humidity Range:	0 to 95% RH
Outline Dimensions:	
Height -	6-13/16 Inches
Width -	6-17/32 Inches
Depth -	17-1/8 Inches
Approximate Net Weight:	20 Pounds
Approximate Shipping Weight:	35 Pounds

RECEIVING, HANDLING, STORAGE, AND SHIPMENT

RECEIVING

On receipt of the controller, examine it immediately for any damage that might have occurred in transit. Immediate examination is especially important if rough handling is evident. If damage is found, a damage claim should be filed immediately with the transportation company, and the nearest General Electric apparatus sales office should be notified promptly.

HANDLING

The controller is a rugged electronic unit weighing approximately 20 pounds. Observe normal precautions for electronic equipment during handling.

STORAGE

If the controller is to be stored prior to use, repack it in its original packing material and container, if possible. Store it in an area free from corrosive vapors, excessive vibration and shock, and extremes of temperature. (See Specifications.)

SHIPMENT

If the controller is to be reshipped, repack it in its original packing material and container, if possible. Use a method of shipment which will ensure that normal precautions for electronic equipment are observed.

DESCRIPTION

GENERAL

The Type 524 Current-Modulation Controller consists of a case and mounting bracket assembly and the controller assembly. (See Fig. 1, Fig. 2, and Fig. 3.)

CASE AND MOUNTING BRACKET ASSEMBLY

The case and mounting bracket assembly encloses the controller assembly, and provides for convenient panel-mounting of the controller. (See Fig. 1, Fig. 2, and Fig. 3.) A terminal board on the rear of the case provides for external electrical connections. This terminal board is protected by a cover plate. Cabling or conduit is routed to the terminal board through conduit holes in the rear of the case. A cable assembly (3) and plug (4) connect the case terminal board to the connector (12) at the rear of the controller assembly. (See Fig. 3.) The fuse (5) which protects the power circuit is located in this plug.

CONTROLLER ASSEMBLY (See Fig. 3 and Fig. 4.)

General (See Fig. 3.)

The controller assembly consists of the control unit (10) with operating controls and adjustments, the control amplifier (11), and the manual-control circuit board (13).

Front Control Panel (See Fig. 4.)

The front control panel contains the most frequently used controls and indicators. They are the indicating meter (1), the POWER lamp (2), the LIMIT lamp (3), the AUTO. BAL. MAN. transfer switch (4), and the MANUAL control (5).

Side Control Panel (See Fig. 4.)

The side control panel contains the controls and adjustments normally used only when the controller is first put in operation. These controls and adjustments seldom require readjustment during operation of the controller with an established process. They are the LOAD ADJ OHMS adjustment (6), the INSTR CAL. adjustment (7), the PROP BAND ADJ pushbutton (8), the PROP BAND PERCENT control (9), the RESET R M control (10), and the RATE MIN control (11). Also mounted on the side control panel are the output test jacks (12 and 13).

Control Amplifier (See Fig. 5.)

The plug-in control amplifier is of solid-state construction and includes a self-contained power supply. In addition, it contains a regulated power supply for operation of the control-slidewire circuit in the related recorder. When the controller is operated manually, the control amplifier may be removed for servicing without affecting the controller output.

Manual-Control Circuit Board

The plug-in manual-control circuit board contains a full-wave rectifier and a transistor regulator. It supplies the controller output current during manual operation, and also permits operation of the controller with the control amplifier removed.

Process Legend Clips (See Fig. 3.)

The two spring clips on the back of the door may be used to clip a process identification tag on the lower inside of the door.

SPECIAL SERVICE TOOLS

No special service tools are required to install, operate, and maintain the controller.

INSTALLATION

GENERAL

Install the controller in an area free from corrosive vapors, excessive vibration and shock, and extremes of temperature. (See Specifications.) In addition, mount the controller a reasonable distance from transformers or conductors carrying high currents. Outline and mounting dimensions and panel spacing requirements are shown in Fig. 2 and Fig. 3.

PROCEDURE

1. To facilitate panel mounting, remove controller assembly from case and mounting bracket assembly. (See Fig. 3.)

CAUTION

Place case on edge of bench or on one-inch-high support to avoid cracking hinges when opening door.

- a. Press latch release at top of case, and lower door clear of front panel.
- b. Press centrally located latch bar on front panel, and partially withdraw controller assembly, releasing latch. Assembly will lock in half-extended position.
- c. Press latch lever under controller assembly, and withdraw controller assembly farther, supporting it at base. Assembly will catch in fully extended position.

- d. Disconnect plug from connector at rear of controller assembly.
- e. Lift controller assembly up and out, and, supporting assembly at base, remove it from case. Set controller assembly aside in safe place.
2. Remove adjustment screw from mounting bracket, detaching mounting stud by pushing it toward front of case. (See Fig. 6.)
3. Insert case into panel opening from front, and slide mounting bracket into position from rear. (See Fig. 6.)
4. Replace mounting stud, locking it by pressing it while holding mounting bracket in position. Clamp case firmly to panel by replacing and tightening adjustment screw. (See Fig. 6.)
5. Remove rear cover to gain access to terminal board. Make external connections to terminal board on rear of case in accordance with Fig. 7. Remove plug buttons from rear of case, and route conduit or cabling through holes provided. Refer to rating plate on controller for controller voltage and frequency ratings. When replacing terminal board cover, position locking lugs so as to engage lip of case when screws are tightened.

NOTE: Do not install signal leads in same conduit with power leads. Make sure all connections are tight. Refer to the notes on Fig. 7 for information on the relation of controller output current increase to recorder pen-pointer movement, and for information related to connections applicable to snap-action limit switches on recorder.

6. Replace controller assembly in case by reversing steps e through h of step 1.

OPERATION

OPERATING LIMITS

Refer to the Specifications paragraph of these instructions for allowable operating limits.

INITIAL SERVICING

No initial servicing of the controller is required.

INITIAL OPERATION

General

Before placing the controller in service for the first time, perform the following tests and adjustments on the controller and its companion recorder in the order listed. (See Fig. 1, Fig. 3, Fig. 4, Fig. 7, and Fig. 15.)

Controller Assembly Withdrawal

To gain access to internal controller adjustments, withdraw the controller assembly partially from its case. (See Fig. 3.)

Recorder Adjustments

1. With power OFF, position recorder set-pointer at desired control point on recorder scale.
2. If used, check snap-action limit switch adjustments in recorder. (Refer to Fig. 7 for description of purpose and use of these switches.)

Controller Adjustments (See Fig. 4.)

1. With power OFF, disconnect one of load leads (TB1-6 or TB1-7) from terminal board at rear of case.
2. Measure d-c resistance of controller load (final-control element) with ohmmeter. Denote this resistance value R_L .
3. Adjust LOAD ADJ OHMS adjustment, on side panel of control unit for dial reading of R_L . Use slot in shaft as indicator.
4. Reconnect load lead disconnected in step 1.

Preliminary Control Settings (See Fig. 4.)

1. With power OFF, make preliminary control settings in accordance with Table I.

TABLE I
PRELIMINARY CONTROL SETTINGS

Front Panel Controls		Side Panel Controls	
Control	Setting	Control	Setting
AUTO. BAL. MAN. Transfer Switch	MAN.	PROP BAND PERCENT	100
MANUAL control	Fully CCW (Zero Output)	RESET R, M	Minimum (Less than 0.04 Repeat Per Minute)
		RATE MIN	Minimum (Less than 0.1 Minute)

OPERATING PROCEDURE

General

An indicating meter, a POWER lamp, a LIMIT lamp, an AUTO. BAL. MAN. transfer switch, and a MANUAL control are mounted on the front panel of the controller. With the transfer switch in the MAN. or AUTO. position, the indicating meter reads controller output current in percent. (0% represents an output current of 10 ma, and 100% represents an output current of 50 ma.) With the transfer switch in the BAL. position, the indicating meter reads the difference between the control amplifier output current and the manual control power supply output current. This difference is zero when the meter pointer is aligned with the red dot in the center of the scale. The POWER lamp indicates when the controller is energized. When limit switch No. 1 in the companion recorder is used, the LIMIT lamp indicates when the No. 1 limit has been exceeded and controller output current reduced to 0 ma. The AUTO. BAL. MAN. transfer switch determines the control method (manual or automatic) and meter reading. The MANUAL control adjusts the output current

Manual Operation

1. Energize process system, including recorder and controller.
2. Adjust process with MANUAL control, on front panel, until process stabilizes at desired value.

Manual-to-Automatic Transfer

1. Turn AUTO./BAL./MAN. transfer switch, on front panel, to AUTO. position.

NOTE: Controller can be transferred from manual to automatic operation without causing a "bump" in response. However, if recorder pen-pointer is not aligned with the set point, transfer to automatic control will change current to output load in order to bring process to set point. If manual operation has stabilized at a desired point other than set point, reposition set point before transferring to automatic operation, so that process will remain at point stabilized **under manual control**.

Automatic Operation

General

Optimum process control is obtained by adjusting the PROP BAND PERCENT, RESET R M, and RATE MIN controls on the side panel. The proper control settings depend on the response characteristics of the particular process. Usually, a control setting which produces good control of small variations in the process will also provide satisfactory "process startup" characteristics. In general, a process which requires a relatively fast change in control requirements will require a high setting of the RESET R M control and a low setting of the RATE MIN control. Processes which exhibit large response changes for relatively small controller changes require a high PROP BAND PERCENT control setting.

There are many methods for determining process control settings. Many complex processes may be tuned for good control in minimum time using the "Ultimate Period" method, which is described in a later paragraph. However, some processes may not exhibit the oscillation required in using this method. Because processes such as an electric furnace with a sensing thermocouple may be practically represented by a single time constant, the gain of the controller may not be sufficient to bring the process into oscillation. Under these conditions, the PROP BAND PERCENT control will usually be finally set very narrow (between 5% and 20%). The RATE MIN control may usually be set near minimum (0.1 minute). The RESET R M control should be set for as high a repeats per minute as possible, consistent with good startup, minimum overshoot, and process stability. Two initial startup methods for processes are described separately in the following paragraphs.

Initial Startup for Simple Process

1. Make preliminary control settings in accordance with Table I.
2. Stabilize process at desired operating point in manual operation.
3. Transfer process from manual to automatic control and let process stabilize. If process is not stable, increase setting of PROP BAND PERCENT control until stability is achieved.
4. Decrease setting of PROP BAND PERCENT control in small decrements. Introduce small disturbance into system after each decremental adjustment, to determine system response to new setting.

NOTE: PROP BAND ADJ pushbutton must always be depressed and held during adjustment of PROP BAND PERCENT control, and released after such adjustment to observe process control. This prevents "bumps" in controller output current. Always allow sufficient time for process to stabilize after each adjustment.

5. Use Fig. 8 and Fig. 9 as guides in determining PROP BAND PERCENT control setting.
6. After determining approximate PROP BAND PERCENT control setting, increase setting of RESET R/M control in small increments. Introduce small disturbance into system after each incremental adjustment, to determine system response to new setting.
7. Use Fig. 10 and Fig. 11 as guides in determining RESET R/M control setting. It is desirable to have the maximum reset (in repeats per minute) consistent with process stability, minimum steady state offset, and good startup characteristics.

NOTE: As reset (in repeats per minute) is increased, process stability is decreased.

8. After determining approximate PROP BAND PERCENT and RESET R M control settings, increase setting of RATE MIN control in small increments. Introduce small disturbance into system after each incremental adjustment, to determine system response to new setting.

9. Use Fig. 12 and Fig. 13 as guides in determining RATE MIN control setting.

NOTE: As RATE MIN control setting is increased, it may be necessary to decrease PROP BAND PERCENT control setting and or RESET R M control setting slightly. The product of the reset setting in repeats per minute and the rate setting in minutes should not exceed 1.0. For example, if reset setting is 2.0 repeats per minute, rate setting should not exceed 0.5 minute.

10. After initial control settings have been made, test system for control over expected range of set points. It may be necessary to readjust control settings slightly to maintain optimum performance at various set points.

Initial Startup for Complex Process

The "Ultimate Period" method of control adjustment usually results in excellent control performance for processes which may be represented by a combination of dead times and time constants. The following procedure outlines this method.

1. Make preliminary control settings in accordance with Table I.
2. Stabilize process at desired operating point in manual operation.
3. Transfer process from manual to automatic control and let process stabilize. If process is not stable, increase setting of PROP BAND PERCENT control until **stability is achieved.**

4. Press PROP BAND ADJ pushbutton, and simultaneously decrease PROP BAND PERCENT control setting in small decrements.

NOTE: Pushbutton must always be depressed and held during adjustment of PROP BAND PERCENT control, and released after such adjustment to observe process control. This prevents transient "bumps" in controller output.

5. Continue to decrease setting of PROP BAND PERCENT control in small decrements until recorder pen-pointer cycles at constant amplitude. Allow sufficient time after each decremental adjustment for process to stabilize. Some processes may require a small disturbance (such as a small change in recorder set point) to start process cycling.

6. Measure time in minutes for one complete cycle, and note this time as t .
7. Note setting of PROP BAND PERCENT control as PB.
8. Adjust PROP BAND PERCENT control for a setting of 2 to 3 times PB.
9. Adjust RESET R/M control for a setting of $2/t$.
10. Adjust RATE MIN control for a setting of $t/8$.
11. Make final adjustments of controls listed in steps 7, 8, and 9 to obtain optimum response characteristics.

- a. To prevent excessive cycling, increase setting of PROP BAND PERCENT control, and/or decrease setting of RESET R/M control.

- b. To prevent excessive overshoot at startup, decrease setting of RESET R/M control.
- c. To prevent excessive overshoot within proportional band, increase setting of RATE MIN control.
- d. To correct undershoot, increase setting of RESET R/M control, and/or decrease setting of RATE MIN control.

11. Record all three final control settings.

Automatic Process Startup

Once the final control settings have been established, the controller will effect a process startup free of reset windup. If a startup having a minimum of overshoot is of primary importance, minor changes in control settings may be made without appreciably affecting process control. Excessive overshoot in process startup can be eliminated by a small decrease in the setting of the RESET R/M control. Undershoot can be corrected by a small increase in this setting.

Automatic-to-Manual Transfer

1. Turn AUTO. /BAL. /MAN. transfer switch, on front panel, to BAL. position.
2. Adjust MANUAL control, on front panel, until pointer of indicating meter rests at red dot on scale.
3. Turn AUTO. /BAL. /MAN. transfer switch, on front panel, to MAN. position. Output current is now controlled by MANUAL control.

PRINCIPLES OF OPERATION

GENERAL

The Type 524 Current-Modulation Controller is installed with a General Electric Type HF, HR, HT, 520, or 521 strip-chart recorder, all of which have a 5.0K 100% control slide wire or a provision for adding one. The function of the controller is to provide a 10 to 50 ma control signal for a final-control element such as a magnetic amplifier and saturable reactor, an electro-pneumatic or electro-hydraulic valve operator, or a silicon controller-rectifier. The Type 524 Current-Modulation Controller provides both manual and automatic process control. A simplified functional diagram of a typical controller is shown in Fig. 14. A complete schematic diagram of such a controller is shown in Fig. 15. The schematic diagram of a typical control amplifier is shown in Fig. 16.

An indicating meter (M101), a POWER lamp (DS1), a LIMIT lamp (DS2), an AUTO. BAL. /MAN. transfer switch (S1), and a MANUAL control (R111) are mounted on the front panel of the controller. With S1 in the MAN. or AUTO. position, M101 reads controller output current in percent. (0 represents an output current of 10 ma, and 100% represents an output current of 50 ma.) With S1 in the BAL. position, M101 indicates the difference between the control amplifier output current and the manual control power supply output current. This difference is zero when the meter pointer is aligned with the red dot in the center of the scale. POWER lamp (DS1) indicates when the controller is energized. When limit switch No. 1 in the companion recorder is used, LIMIT lamp (DS2) indicates when the No. 1 limit has been exceeded and

controller output current reduced to 0 ma. AUTO. BAL. MAN. transfer switch (S1) determines the control method (manual or automatic) and M101 reading. MANUAL control (R111) adjusts the output current from the manual control power supply.

In both manual and automatic control, the controller supplies a 10 to 50 ma output current to a $0 \text{ to } 600 \pm 10\%$ ohms external load. Test jacks J4 and J5 are connected across a test resistor (R116) to facilitate calibration and testing. This circuit arrangement provides test signals of 10 to 50 millivolts. The LOAD ADJ OHMS potentiometer (R112) is set for a dial reading equal to the resistance value of the external load, using the slot in the shaft as an indicator. This insures that the control amplifier load is approximately 600 ohms, regardless of the value (between 0 and 600 ohms) of the external controller load. The INSTR CAL potentiometer (R113) adjusts the bias current through the indicating meter (M101) when the AUTO. BAL. MAN. transfer switch (S1) is in the AUTO. or MAN. position. This current is obtained from the manual control power supply. It biases M101 so that it reads controller output current in percent, as described in the preceding paragraph.

MANUAL OPERATION

During manual operation, the output current to the external load is supplied by the zener-diode-regulated variable power supply. The MANUAL control potentiometer (R111) adjusts the base current of transistor Q201 to provide an adjustable current between 10 and 50 milliamperes.

MANUAL TO AUTOMATIC TRANSFER

During manual operation, the input to the control amplifier is connected differentially between resistors R204 and R205. This input is thus proportional to the difference between the manual control current and the control amplifier output current. The output current of the control amplifier is forced to equal the output current of the manual supply. Therefore, the controller may be transferred from manual to automatic operation without introducing a change in output current to the external load. No preliminary adjustments or balancing procedures are required.

AUTOMATIC OPERATION

General

During automatic operation, the 10 to 50 ma output current to the external load is supplied by the control amplifier. The value of this output current is determined by the error signal connected to the controller input terminals, and is such as to control the process at the recorder set point.

This error signal is obtained from the control slidewire in the companion recorder. The slidewire is a two-turn helix preventing the sliding contact from "running off the end" of the slidewire if the pen-pointer and the set-pointer are positioned at opposite scale extremes. The slidewire is connected as part of a bridge circuit, which includes resistors R101 and R102 in the controller. The bridge supply voltage is provided by the control amplifier in the controller.

When the pen-pointer and the set-pointer are aligned on the recorder scale, the wiper of the control slidewire is at the electrical center of the slidewire, the bridge circuit is balanced, and the error signal is zero. If the pen-pointer and the set-pointer are not aligned, an error signal proportional in magnitude and responsive in polarity to the misalignment is produced by the bridge circuit.

The input, output, and feedback networks of the control amplifier are used to obtain a wide range of response characteristics in the controller. Controller output current is modified by control circuits to provide an output current with the desired control characteristics.

Proportional Control

Controller output current is proportional to the input error signal by a degree governed by the setting of the PROP BAND PERCENT control (R3), and **controller** gain assumes the following relationship:

$$\text{Controller Gain} = \frac{100\%}{\text{Proportional Band}} = \frac{\text{Percent Output Current Change}}{\text{Percent Input Signal Change}}$$

The $\pm 100\%$ controller input range is $\pm 4V$.

The degree of proportional control action depends on the value of the input error signal applied to capacitor C1, and the amount of negative feedback applied to capacitor C2. Increasing the negative feedback reduces **controller** gain. The proportional band is thus widened because the feedback is proportional to the controller output current.

The PROP BAND ADJ pushbutton (S2) is provided to permit adjustment of the PROP BAND PERCENT control (R3) with the controller in automatic operation, without producing a "bump" in controller output current because of a change in the charge on capacitor C2. When S2 is in its normal position capacitor C103 shunts the controller feedback circuit and is charged by the feedback voltage. Pressing S2 opens the "ground" connection to C103, and reconnects C103 to the control amplifier input, which is now shunted by C5 and R10. Simultaneously, S2 removes the control amplifier input from the junction of R1 and C1 and "grounds" this junction. Also, resistor R7 is connected to "ground" by S2. Because the control amplifier input signal is relatively small in magnitude, the charge from capacitor C103 predominates and prevents feedback current from flowing, thus holding the controller output current constant.

With the PROP BAND ADJ pushbutton (S2) depressed, adjustment of the PROP BAND PERCENT control (R3) charges capacitor C2 to a new level. Releasing S2 restores the normal connections without affecting the controller output current.

Rate Control

With the RATE MIN control (R2) set at minimum, the controller output current changes are directly related to the rate of change of the input error signal. To provide an adjustable output current component proportional to this rate of change (in addition to the proportional output current component), the RATE MIN control (R2) and capacitor C2 are inserted in the controller feedback circuit. The resultant "lagging" RC time constant in the feedback circuit produces a "leading" controller gain characteristic. Since the value of capacitor C2 is fixed, the time constant is determined by the R2

setting. A change in the value of the input error signal results in an output current change (from the controller) of a maximum approximately ten times greater than that produced by the action of the proportional control circuit alone. This increased change in the output current is present only during a changing input error signal. It does not occur when the error signal is of constant value.

Reset Control

Reset control action applies a corrective signal to the amplifier input for the purpose of reducing offset (a small discrepancy between the settings of the recorder pen-pointer and the recorder set-pointer) to a negligible value. The RESET R/M control (R1) and capacitor C1 form an RC time constant circuit with the time constant determined by the setting of potentiometer R1. A continuous offset error results in a steady corrective current through R1 to correct the controller output current by integrating the offset error. The rate of change (during correction) is determined by the degree of offset error, the setting of the RESET R/M control (R1), and the level of operation set by the PROP BAND PERCENT control (R3). Reset time is governed by the time constant of R1 and C1, and the ratio of resistance values of the signal-voltage-dividing resistors (R4 and R5).

Limiting diodes CR21 and CR22 in the control amplifier prevent reset windup during process startup. They limit the value of the error signal applied to the control amplifier, and produce a lead network at the amplifier input when a large error signal is present. During process startup, the control amplifier output can become saturated, if a large error signal has been present during shutdown. As recorder pen-pointer and recorder set-pointer approach a

balanced position, the reset circuit (R1, C1, R4, and R5) reduces the error signal (before a balance is reached) to prevent startup overshoot. The limiter diode circuit causes the amplifier to come out of saturation approximately one reset time period before the process variable reaches the set point.

Control Amplifier

The control amplifier is a d-c operational amplifier using a 1 400 cps carrier frequency. The amplifier input impedance is approximately 2 megohms.

The d-c millivolt error signal is converted to an a-c signal by transistor chopper Q21. This a-c signal is amplified by an a-c amplifier consisting of transistors Q22, Q23, and Q24. The output is then demodulated by a ring demodulator (CR27 through CR30) and filtered. The filtered d-c signal is further amplified by a d-c amplifier consisting of Q25 and Q26. The Q26 output is used in two ways. First, it produces feedback voltage across the proportional band circuit for function generation of proportional, reset, and rate control. Secondly, it is converted to a-c by transistor chopper Q27, and coupled to output transistor Q30 by isolation transformer T23. Output transistor Q30 demodulates and provides power amplification, to produce a 10 to 50 ma output current into a 600-ohm load. Potentiometers R47 and R54, respectively, adjust the zero and offset of the control amplifier.

A unijunction oscillator (Q28) and an amplifier (Q29) provide the 1,400 cps chopper carrier frequency.

The control amplifier contains its own d-c power supplies. A half-wave power supply with a zener reference diode (CR38) provides an 8-volt source for the recorder slidewire.

Limit Switch Circuits

When limit switch No. 1, on the companion recorder, is used, the jumper between TB1-13 and TB1-14 on the terminal board at the rear of the controller case is removed. If limit No. 1 is then exceeded, LIMIT lamp (DS2) lights, the control amplifier is de-energized, and the controller output current drops to 0 ma.

When limit switch No. 2, on the companion recorder, is used, the jumper between TB1-10 and TB1-11 on the terminal board at the rear of the controller case is removed. If limit No. 2 is then exceeded, the controller output current becomes a constant 50 ma, which is provided by the manual control power supply. In this case, LIMIT lamp (DS2) remains off.

AUTOMATIC TO MANUAL TRANSFER

A transfer of controller operation from automatic to manual can be made during operation without introducing a change in controller output current. Prior to the transfer, the AUTO. BAL. MAN. transfer switch (S1) is turned to the BAL. position. This connects the indicating meter (M101) differentially between resistors R204 and R205, but leaves the output of the control amplifier connected to the load. Meter M101 now reads the difference between the control amplifier output current through the external load and the manual control power supply current through dummy load resistor R115. The MANUAL control (R111) is used to adjust the manual control power supply current equal to the control amplifier output current by aligning the red dot on the meter scale with the meter pointer. (The controller remains in automatic operation during the balance.) A transfer from automatic to manual operation may then be made without introducing a change in the output

MAINTENANCE

PREVENTIVE MAINTENANCE

No periodic maintenance procedures are required.

CORRECTIVE MAINTENANCE

Tests and Adjustments

Indicating Meter Adjustment

If indicating meter does not have meter pointer aligned with red dot on meter scale with controller de-energized, adjust it for a zero reading with screw adjustment on meter case (inside front panel).

If it is suspected that indicating meter is not reading controller output current correctly, perform the following steps in the order listed.

NOTE: AUTO. /BAL. MAN. transfer switch must be in AUTO. or MAN. position for this adjustment.

1. Connect a potentiometer capable of measuring a 50 millivolt signal between test jacks on side panel. A 10-millivolt potentiometer reading should correspond with a 0% indicating meter reading, and a 50-millivolt potentiometer reading should correspond with a 100% indicating meter reading.

2. If correct indicating meter readings are not obtained, adjust INSTR CAL potentiometer, on side panel, for correct readings. Required calibration accuracy is $\pm 3\%$.

Control Amplifier Zero and Offset Adjustments (See Fig. 2.)

NOTE: The control amplifier zero and offset adjustments (R47 and R54) are properly adjusted at the factory, and, under ordinary circumstances, should require no readjustment. However, if the amplifier zero or offset is suspected to be incorrect, perform the following steps in the order listed.

1. Prepare test set-up shown in Fig. 17.
2. Remove control amplifier cover.
3. Connect jumper between TEST PT. A and TEST PT. B on control amplifier printed circuit board.
4. Adjust zero potentiometer (R47), on control amplifier, for voltmeter reading of 18 ± 1 VDC.
5. Remove jumper between TEST PT. A and TEST PT. B on control amplifier printed circuit board.
6. Replace control amplifier cover and tighten screws which secure it.
7. Using screwdriver with insulated shaft, adjust offset potentiometer (R54) on control amplifier, for voltmeter reading of 18 ± 6 VDC. Adjust R54 through hole in top of amplifier cover.

NOTE: Since the control amplifier is not in a closed loop, a slow drift toward one or the other end of the voltmeter scale will be noted.

8. Disconnect test set-up shown in Fig. 17.

Repair and Replacement

General

If a component is to be returned to the factory for repair, obtain shipping instructions from the nearest General Electric apparatus sales office.

WARNING

USE CARE WHEN WORKING ON A CONTROLLER COMPONENT FROM WHICH THE COVER PLATE HAS BEEN REMOVED. DE-ENERGIZE CONTROLLER PRIOR TO REMOVAL OF ANY COMPONENT, AND RE-ENERGIZE CONTROLLER ONLY AFTER REPLACEMENT OF COMPONENT AND TIGHTENING OF CONNECTIONS.

Cover Plates

Major sections of the controller are protected by cover plates, which can be removed for inspection or adjustments. The control unit cover plate is secured by a captive screw in its center. The control amplifier cover plate is secured by two screws. The chassis bottom cover plate is secured by two screws at the rear of the chassis. This plate is removed by extracting the two screws and withdrawing the plate from the supporting grooves.

Control Amplifier Removal

NOTE: During manual operation of the controller, the control amplifier is not used, and can be removed for servicing. Use the following procedure to remove the control amplifier.

1. Withdraw controller assembly from case to point just beyond half-extended position.
2. Push control amplifier holdown, on bottom of controller assembly, up and toward rear of chassis, so that holdown lug clears slot in bottom of control amplifier.
3. Continue controller assembly withdrawal until control amplifier is clear of case, and unplug amplifier from chassis.

NOTE: To replace control amplifier, reverse steps 3 through 1.

Manual Control Supply Board Removal

NOTE: The manual control supply board must not be removed with the controller in operation.

1. Remove control amplifier as described in the preceding paragraph.
2. Loosen captive screw in center of control unit cover plate, and remove cover plate.
3. Remove screw near lower left corner of board.
4. Grasp top edge of board with fingers, and withdraw board from control unit with slight rocking motion.

NOTE: To replace manual control supply board, reverse steps 4 through 1

Door Replacement

Use the following procedure to replace the door on the controller case.

1. Push in left and right pivot rods at bottom of door, maneuvering door so that rods remain pushed in. Use a bent paper clip or similar device to push in rods by inserting it through holes in door.

2. Remove door from case.

NOTE: Do not lose or misplace o-rings on pivot rods.

3. Slide new door over one pivot rod.

4. Push in other pivot rod with bent paper clip or similar device, and snap door over this rod, making sure that o-ring is in place.

Semiconductor Replacement

When replacing diodes or transistors, use extreme care to prevent heat from the soldering iron from damaging the component. Whenever possible, use long-nose pliers as a heat sink by holding the component lead with the pliers during the soldering operation.

Renewal Parts

Renewal parts, such as capacitors and transistors, should be obtained locally. If they cannot be obtained locally, they can be ordered from the nearest General Electric apparatus sales office. When ordering renewal parts, identify the part as completely as possible, giving the complete catalog number, if available, and any other identification, such as the reference designation on the wiring diagram. Also include on the order the quantity required and the complete model number of the controller (on the rating plate inside the case).

TROUBLE SHOOTING

It is recommended that only a qualified electronic technician be allowed to service or trouble shoot the controller. When trouble shooting the controller, refer to the schematic diagrams of Fig. 15 and Fig. 16. If trouble in a system has been isolated to the controller, use Table II as a trouble shooting guide.

CAUTION

ALWAYS DE-ENERGIZE CONTROLLER BEFORE
MAKING OHMMETER CHECKS.

TABLE II
TROUBLE SHOOTING CHART

Trouble	Probable Cause	Remedy
1. Controller does not supply output current in either manual or automatic operation.	A. Blown power fuse.	A1. Check power fuse (F1) in play which mates with connector at rear of controller assembly. If fuse (F1) is blown, replace it after determining cause of blowing.
	B. Loss of a-c power.	B1. Measure line voltage between TB1-15 and TB1-16 of terminal board in rear of controller case. If proper line voltage is not present, restore line voltage to correct operation.
	C. Open or shorted connections.	C1. Inspect all pertinent circuitry for loose connections, short circuits, and frayed or broken leads. Correct any defect found.
2. Controller does not supply output current in manual operation.	A. Loss of manual control power supply voltage.	A1. Check manual control board voltages at terminals of jack J3. All voltages are measured with respect to J3-D.
	B. Open or shorted connections.	B1. Inspect all pertinent circuitry for loose connections, short circuits, and frayed or broken leads. Correct any defect found.

TABLE II
TROUBLE SHOOTING CHART (Continued)

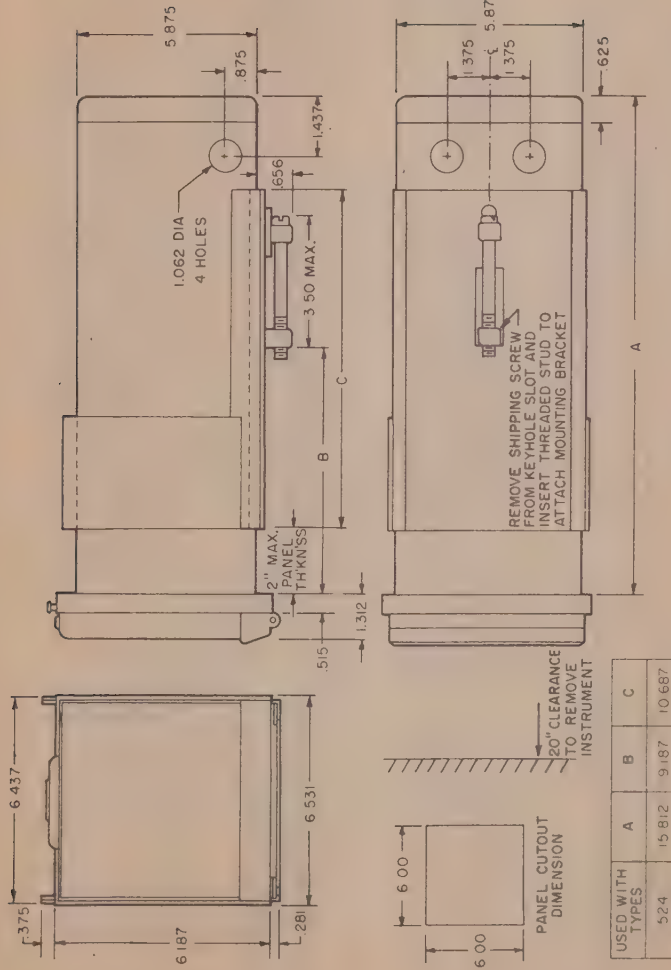
Trouble	Probable Cause	Remedy
3. Controller does not supply output current in automatic operation.	A. Loss of set point supply voltage.	A1. Measure d-c voltage between TB1-1 and TB1-3 of terminal board in rear of controller case. This voltage should read between 7 and 9 volts. If this voltage is not present, check for short or open circuit in wiring external to control amplifier. Correct short or open circuit if found. If no short or open circuit is found, set point supply of control amplifier is defective. Repair or replace defective control amplifier. B. Loss of input error signal. B1. Measure d-c voltage between TB1-2 and TB1-4 of terminal board in rear of controller case. This voltage should vary from +4V to -4V as set point slide-wire in companion recorder is turned from one extreme to the other. If no voltage is present, check pertinent circuit connections. If voltage does not respond smoothly, clean slidewire and

TABLE II
TROUBLE SHOOTING CHART (Continued)

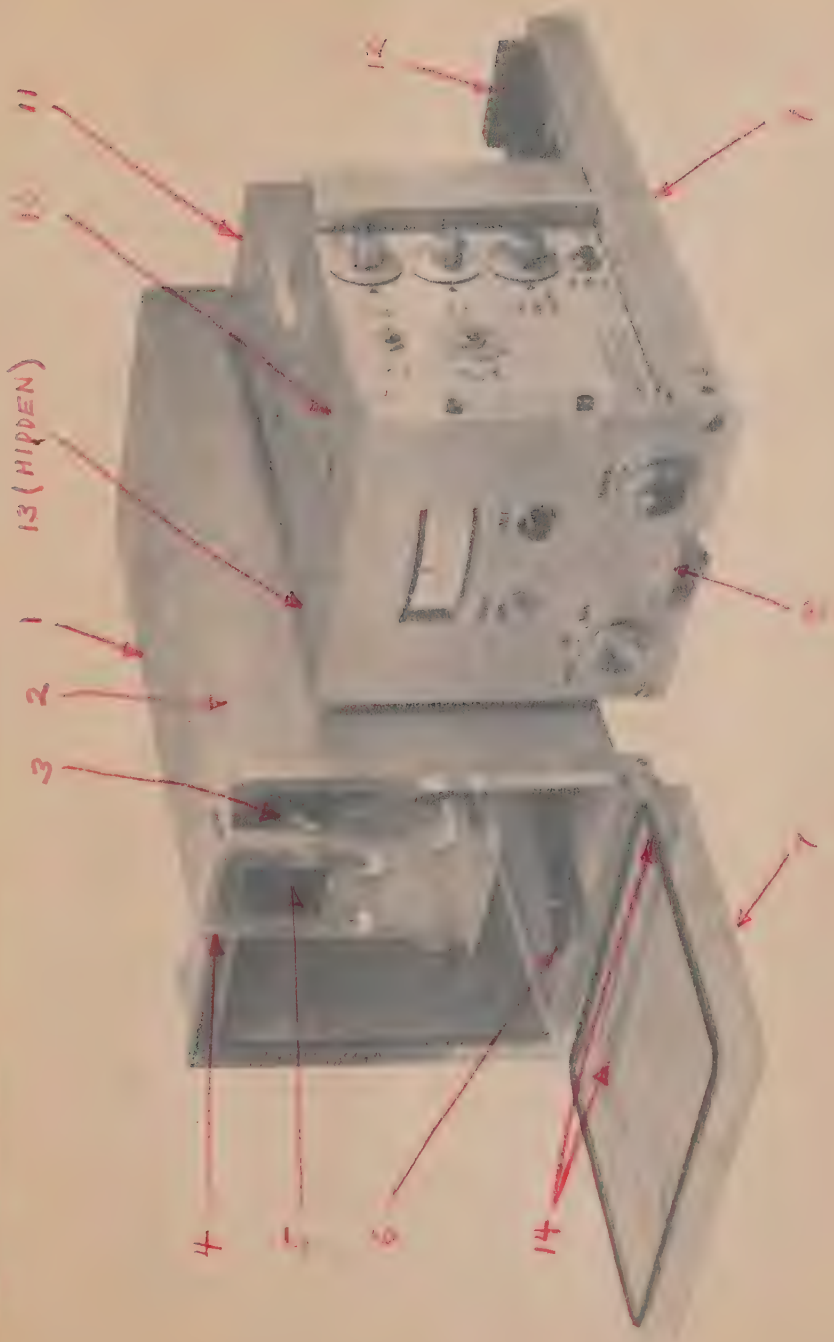
Trouble	Probable Cause	Remedy
		check for good contact of wiper with slidewire mandrel.
	C. Defective control amplifier.	C1. Repair or replace defective control amplifier.
	D. Defective controller circuitry.	D1. Make voltage and resistance checks in pertinent controller circuitry. Repair or replace any component found defective.
	E. Open or shorted connections.	E1. Inspect all pertinent circuitry for loose connections, short circuits, and frayed or broken leads. Correct any defect found.
4. Controller output current is low in both manual and automatic operation.	A. Incorrect adjustment of LOAD ADJ OHMS potentiometer.	A1. Perform steps 1 through 4 of Controller Adjustments subparagraph of Initial Operation paragraph of Operation section.
5. Sluggish controller response is observed in automatic operation.	A. Low control amplifier gain. B. Incorrect control setting.	A1. Repair or replace defective control amplifier. B1. Check settings of all controls. (Refer to Automatic Operation subparagraph of Operating Procedure paragraph of Operation section.)



Fig. 1. Typical automatic weather station



BRACKET ASSEMBLY



13 (HIDDEN)

CONTROLLER ASSEMBLY

Fig. 1. Typical control - modulation system with
controller assembly and power supply

LEGEND

- | | |
|---------------------|----------------------------------|
| 1. CASE | 8. LATCH BAR |
| 2. MOUNTING BRACKET | 9. CHASSIS |
| 3. CABLE ASSEMBLY | 10. CONTROL UNIT |
| 4. PLUG | 11. CONTROL AMPLIFIER |
| 5. FUSE | 12. CONNECTOR |
| 6. LATCH LEVER | 13. MANUAL-CONTROL CIRCUIT BOARD |
| 7. DOOR | 14. PROCESS CLIPS |

Fig. 3. Typical current-modulation controller with controller assembly removed from case (cont.)

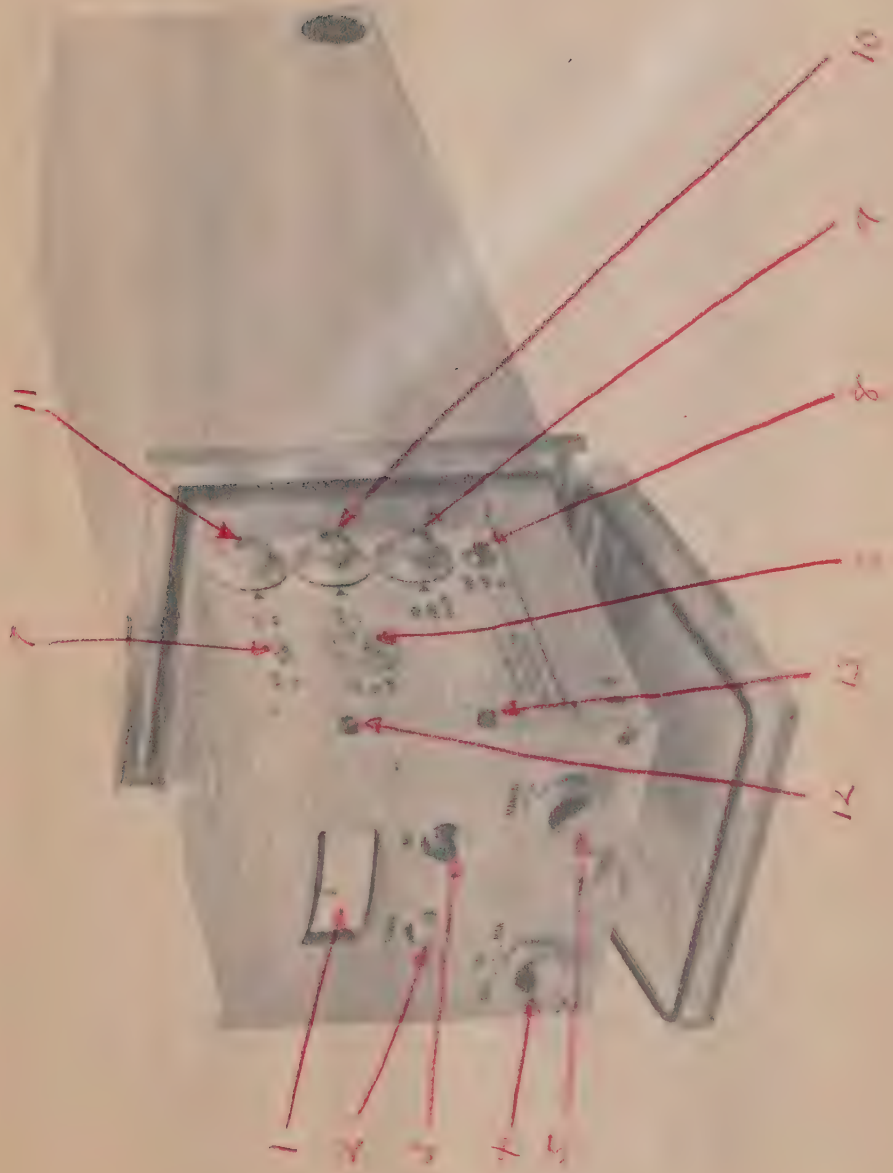


Fig. 7. Typical carburetor with
adjustable needle position

LEGEND

- | | |
|---------------------------------------|-------------------------------|
| 1. INDICATING METER | 8. PROP BAND ADJ PUSHBUTTON |
| 2. POWER LAMP | 9. PROP BAND PERCENT CONTROL |
| 3. LIMIT LAMP | 10. RESET R/M CONTROL |
| 4. AUTO./BAL./MAN. TRANSFER
SWITCH | 11. RATE MIN CONTROL |
| 5. MANUAL CONTROL | 12. POSITIVE OUTPUT TEST JACK |
| 6. LOAD ADJ OHMS ADJUSTMENT | 13. NEGATIVE OUTPUT TEST JACK |
| 7. INSTR CAL. ADJUSTMENT | |

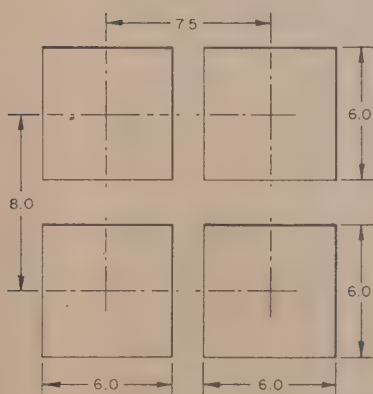
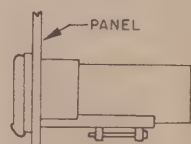
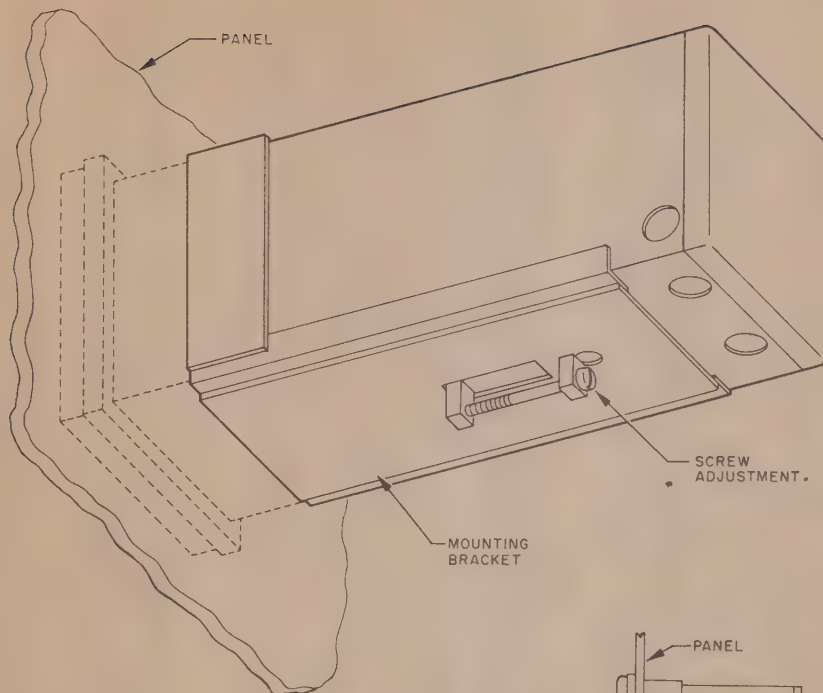
Fig. 4. Typical current-modulation controller with controller assembly in half-extended position (cont.)

A47

TEST PT. A TEST PT. B
(HIDDEN)

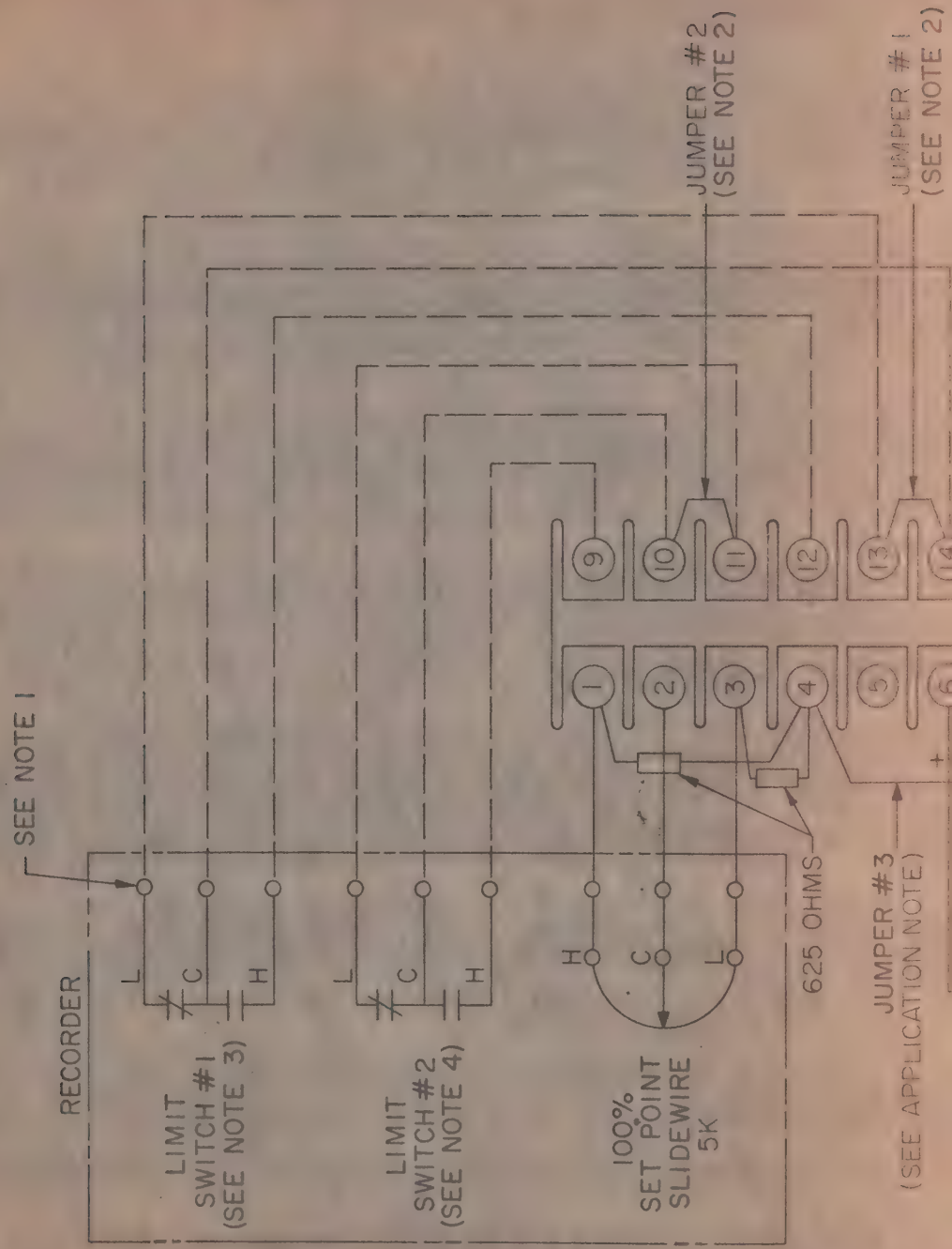
A37

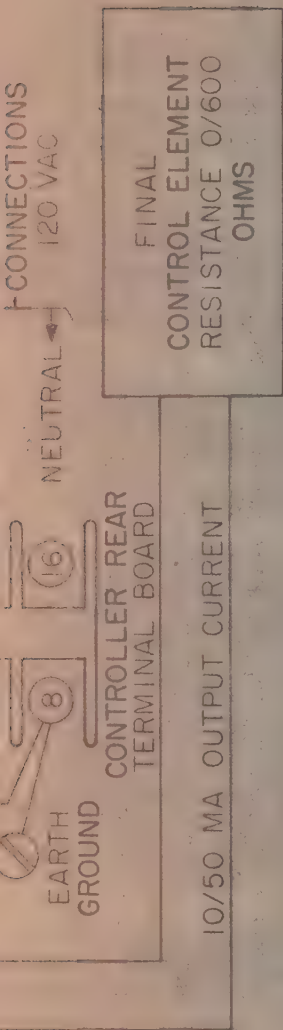
9/4/5, Optical cable amplifier with wave plate mounted



PANEL CUTOUT AND MINIMUM SPACING DIMENSIONS

9/27/72





NOTES:

1. FOR RECORDER TERMINAL NUMBERS, SEE CONTROL DIAGRAM IN RECORDER INSTRUCTIONS.
2. LIMIT ("SNAP-ACTION") SWITCHES ARE NOT REQUIRED FOR CONTROLLER OPERATION. TO USE LIMIT FEATURE, REMOVE APPROPRIATE JUMPER FROM TERMINAL BOARD.
3. IF CONNECTED, LIMIT SWITCH NO.1 WILL DECREASE OUTPUT CURRENT TO ZERO AND LIGHT LIMIT LAMP WHEN OPERATED. REMOVE JUMPER NO.1 WHEN SWITCH IS CONNECTED.
4. IF CONNECTED, LIMIT SWITCH NO.2 WILL INCREASE OUTPUT CURRENT TO MAXIMUM WHEN OPERATED. REMOVE JUMPER NO.2 WHEN SWITCH IS CONNECTED. (LIMIT LAMP WILL NOT LIGHT.)
5. WIRED AS SHOWN, OUTPUT CURRENT INCREASES AND METER GOES TOWARD 100 WHEN RECORDER POINTER MOVES TO LEFT SIDE OF CONTROL POINT.
6. TO REVERSE CONTROL ACTION, INTERCHANGE CONNECTIONS FROM CONTROL SLIDEWIRE TO CONTROLLER TERMINALS 1 AND 3.

APPLICATION NOTE

FOR THOSE APPLICATIONS REQUIRING AN UNGROUNDED INPUT, REMOVE JUMPER NO.3. VOLTAGE FROM INPUT TO GROUND MUST NOT EXCEED ± 30 VDC AND RESISTANCE FROM INPUT TO GROUND MUST NOT EXCEED 1 MEGOHM WHEN INPUT IS NOT GROUNDED.

Fig. 7.

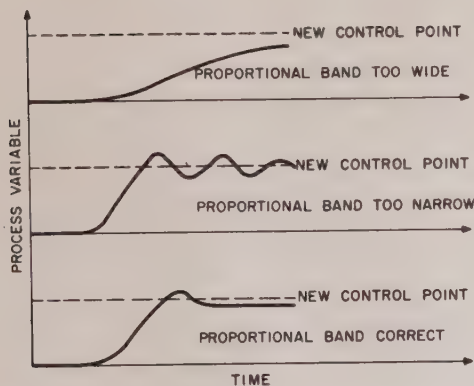


Fig. 8. Typical controller responses to change in set point for different proportional band settings

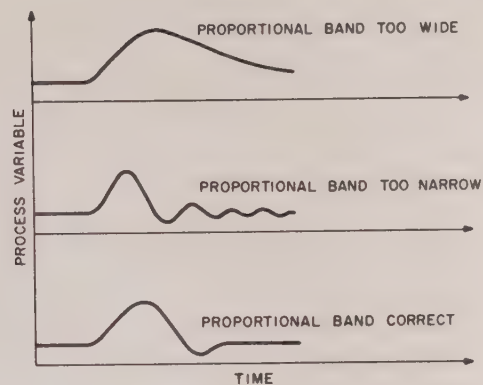


Fig. 9. Typical controller responses to change in demand for different proportional band settings

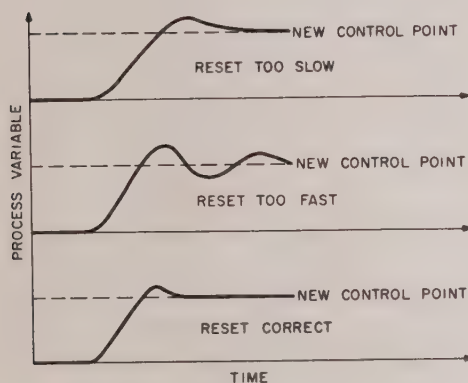


Fig. 10. Typical controller responses to change in set point for different reset settings

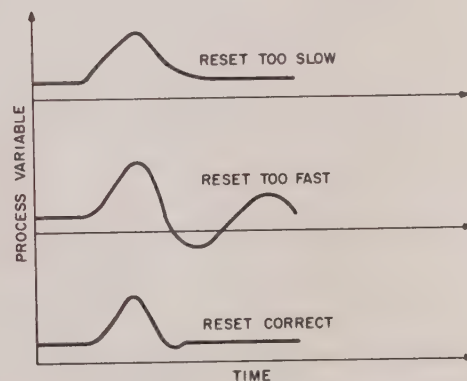


Fig. 11. Typical controller responses to change in demand for different reset settings

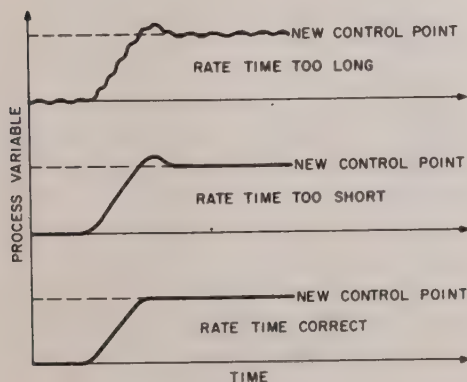


Fig. 12. Typical controller responses to change in set point for different rate settings

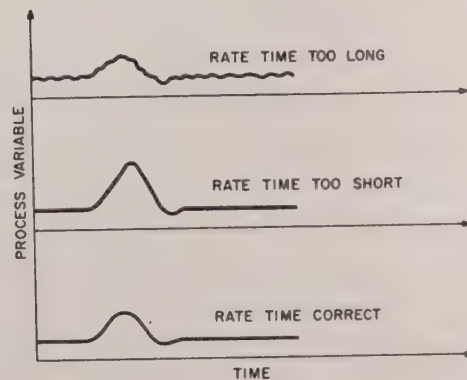
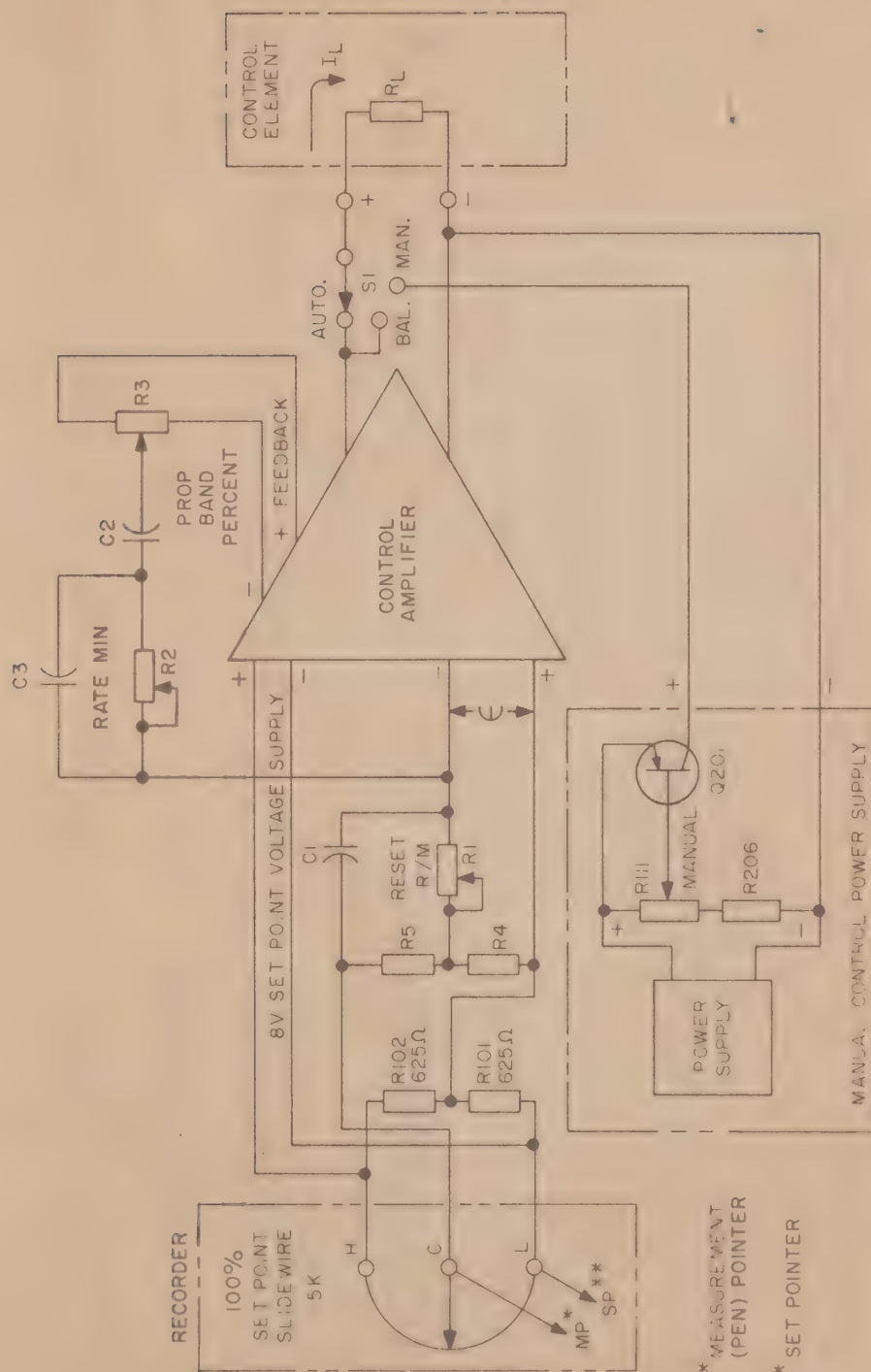


Fig. 13. Typical controller responses to change in demand for different rate settings

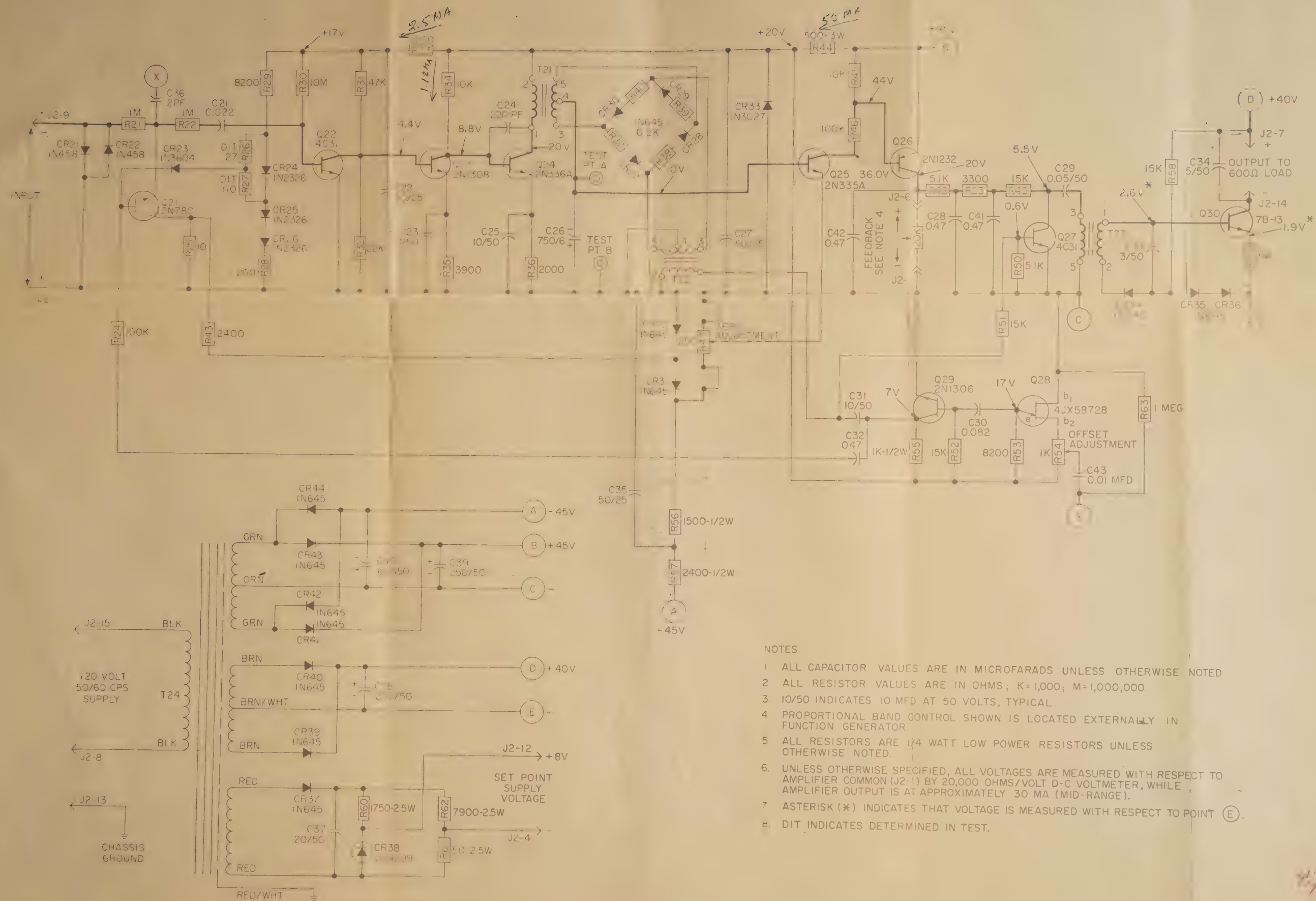


* MEASUREMENT
(PEN) POINTER

SET POINTER

1. ALL CAPACITOR VALUES ARE IN MICROFARADS.
2. ALL RESISTOR VALUES ARE IN OHMS, K=1,000, M=1,000,000.
3. HORIZONTAL VOLTAGE IS 100 VOLTS, TYPICAL.
4. VOLTAGE ARE MEASURED WITH REFERENCE TO POWER SUPPLY GROUND BY A 10,000 OHMS/VT D.C. METER, WHILE CONTROLLER IS ON MANUAL AND METER AT CENTER SCALE.
5. 'X' POINTS ARE LOCATED ON TERMINAL BOARDS UNDER CHASSIS.

FOR THOSE APPLICATIONS REQUIRING AN UNGROUNDED INPUT, REMOVE JUMPER BETWEEN TBI-4 AND TBI-8. VOLTAGE FROM INPUT TO GROUND MUST NOT EXCEED ± 30 VDC AND RESISTANCE FROM INPUT TO GROUND MUST NOT EXCEED 1 MEGOHM WHEN INPUT IS NOT GROUNDED.



NOTES

- 1 ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE NOTED
- 2 ALL RESISTOR VALUES ARE IN OHMS; K=1,000; M=1,000,000.
- 3 10/50 INDICATES 10 MFD AT 50 VOLTS, TYPICAL.
- 4 PROPORTIONAL BAND CONTROL SHOWN IS LOCATED EXTERNALLY IN FUNCTION GENERATOR.
- 5 ALL RESISTORS ARE 1/4 WATT LOW POWER RESISTORS UNLESS OTHERWISE NOTED.
- 6 UNLESS OTHERWISE SPECIFIED, ALL VOLTAGES ARE MEASURED WITH RESPECT TO AMPLIFIER COMMON (J2-1) BY 20,000 OHMS/VOLT D-C VOLTMETER, WHILE AMPLIFIER OUTPUT IS AT APPROXIMATELY 30 MA (MID-RANGE).
- 7 ASTERISK (*) INDICATES THAT VOLTAGE IS MEASURED WITH RESPECT TO POINT (E).
- 8 DIT INDICATES DETERMINED IN TEST.

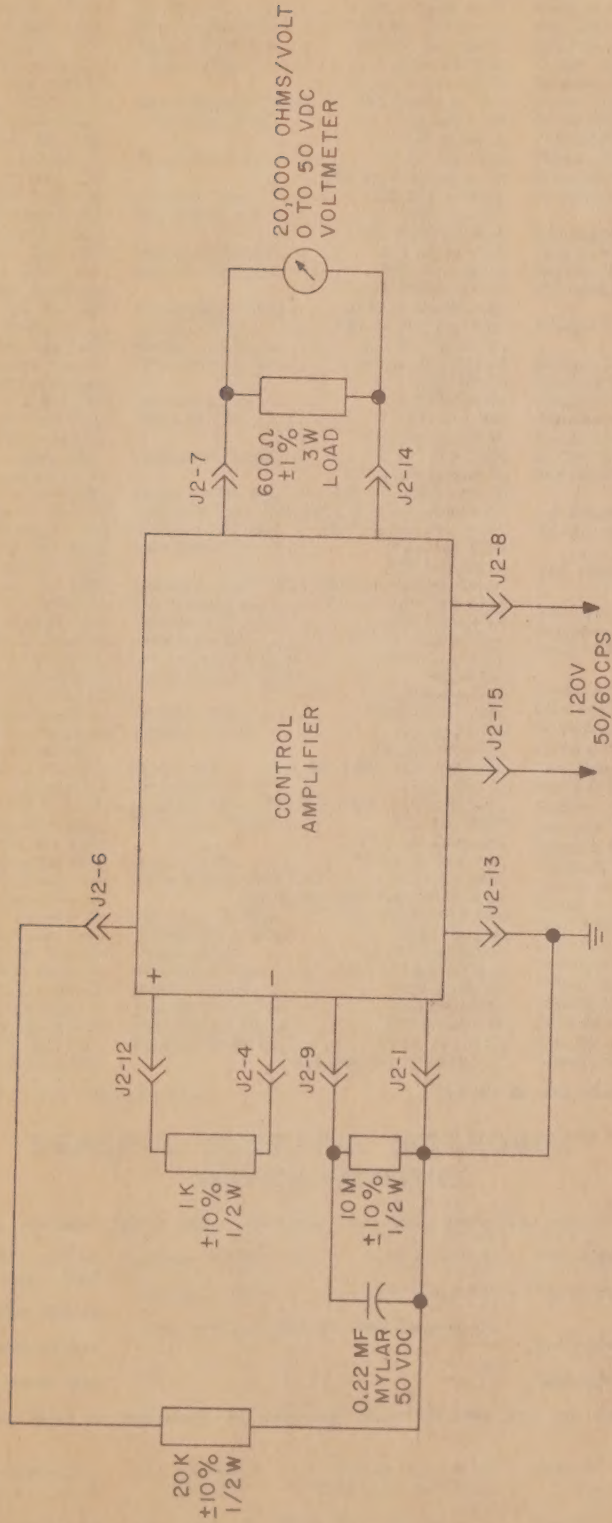


Fig. 17.

GENERAL ELECTRIC APPARATUS SALES OFFICES

GEI-77606F

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Hawaii: American Factors, Ltd., P.O. Box 3230, Honolulu 1

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Chicago 32, Ill.....	4360 West 47th St.	Detroit 2, Mich.....	5950 Third Ave.	Homestead, Pa.....	Box 308 RD-1
Cincinnati 32, Ohio.....	260 W. Mitchell Ave.				Buttermilk Hollow Rd.
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Ohio.....	118 St. Clair Ave., N. E.	California.....	3700 South Broadway	Arizona.....	3308 North 24th St.
Honolulu.....	Hawaii Instrument Service	New York 13.....	Electro-Tech Equipment Co.	Seattle.....	Instrument Laboratory, Inc.
Hawaii.....	1235 Kapiolani Blvd.	New York.....	85 Tenth Ave.	Washington.....	934 Elliott Ave., West

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INSTRUMENT DEPARTMENT, GENERAL ELECTRIC COMPANY, WEST LYNN, MASS.

